American Journal of Epidemiology

Vol. 161, No. 2
Printed in U.S.A.
DOI: 10.1093/aje/kwi013

Self-reported Electrical Appliance Use and Risk of Adult Brain Tumors

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Received for publication December 23, 2003; accepted for publication July 21, 2004.

Electrical appliances produce the highest intensity exposures to residential extremely low frequency electromagnetic fields. The authors investigated whether appliances may be associated with adult brain tumors in a hospital-based case-control study at three centers in the United States from 1994 to 1998. A total of 410 glioma, 178 meningioma, and 90 acoustic neuroma cases and 686 controls responded to a self-administered questionnaire about 14 electrical appliances. There was little evidence of association between brain tumors and curling iron, heating pad, vibrating massager, electric blanket, heated water bed, sound system, computer, television, humidifier, microwave oven, and electric stove. Ever use of hair dryers was associated with glioma (odds ratio = 1.7, 95% confidence interval: 1.1, 2.5), but there was no evidence of increasing risk with increasing amount of use. In men, meningioma was associated with electric shaver use (odds ratio = 10.9, 95% confidence interval: 2.3, 50), and odds ratios increased with cumulative minutes of use, although they were based on only two nonexposed cases. Recall bias for appliances used regularly near the head or chance may provide an alternative explanation for the observed associations. Overall, results indicate that extremely low frequency electromagnetic fields from commonly used household appliances are unlikely to increase the risk of brain tumors.

adult; brain neoplasms; case-control studies; electromagnetic fields; meningioma; questionnaires; risk

Abbreviations: CI, confidence interval; ELF, extremely low frequency; EMF, electromagnetic field(s); OR, odds ratio.

The etiology of brain tumors remains elusive, aside from a small proportion of tumors that have been attributed to ionizing radiation and several familial cancer syndromes (1–3). Reports of an association between overhead power lines and pediatric (4) and adult (5) brain tumor mortality, as well as associations between electrical occupations and brain tumors (6), originally prompted an interest in a potential link between extremely low frequency (ELF) electromagnetic fields (EMF) and brain tumors. Studies suggesting a link between brain tumors and exposure to ELF-EMF, either residential or occupational, have provided generally weak or no evidence of a causal relation (3, 7–9). Notably, experimental data offer no consistent support for an association of ELF-EMF with brain or other cancers, nor have any plausible biologic or physical mechanisms been identified to explain an association (10). It is generally agreed that magnetic fields do not induce mutations. Some investigators, however, have hypothesized that exposure to magnetic fields may promote the occurrence of cancer initiated by other exposures (11).

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Most studies focusing on brain tumors in adults and exposure to residential ELF-EMF have failed to find an association with calculated magnetic field levels, as measured by distance from power lines or spot measurements in homes (12–16), but one study reported an association with wire codes (a classification based on the configuration of nearby residential power lines) (5). None of these studies considered the contribution of other sources of residential EMF exposure, such as electrical appliances, which produce the highest intensity ELF-EMF personal exposures at home.

Measurement studies of appliances have demonstrated that magnetic field strength is highest close to an appliance and decreases rapidly with increasing distance from the appliance, and the strength usually depends on the type of transformer, motor, or heating element used (17–19). Generally, magnetic fields from smaller, hand-held appliances, such as hair dryers and electric shavers, tend to be higher than those from larger appliances, such as electric ovens.

The single study of adult brain tumors and appliance use reported a modest, nonsignificant association of glioma with electric blankets and of meningioma with electrically heated water beds (20). A variety of electrical appliances and residential exposure to overhead power lines have been investigated in relation to brain tumors in children with generally null results in most (21–24), but not all (25), studies. As part of a comprehensive case-control study of brain tumors in adults (26, 27), this study evaluated the use of common household appliances, especially those such as hair dryers and electric shavers, that have potential for high magnetic field exposure to the head.

MATERIALS AND METHODS

Study subjects

This multicenter, hospital-based, case-control study of brain tumors in adults has been described previously in detail (26, 27). Brain tumor cases and controls were recruited in 1994 through 1998 from hospitals serving as regional referral centers for the diagnosis and treatment of brain tumors in three geographic areas (Boston, Massachusetts; Phoenix, Arizona; and Pittsburgh, Pennsylvania). Eligible participants had to be 18 years of age or older, reside within 50 miles (80.47 km) of the hospital, and understand English or Spanish. Institutional review boards at participating hospitals approved the study protocol. Informed written consent was obtained from all participating subjects or their proxy respondents.

Eligible cases were diagnosed with an intracranial glioma or neuroepitheliomatous tumor, meningioma, or acoustic neuroma during hospitalization or within the preceding 8 weeks. Ninety-two percent (n = 782) of cases agreed to participate, and the majority were interviewed within 3 weeks of the qualifying diagnosis. All glioma and meningioma diagnoses and all but four acoustic neuroma diagnoses were histologically confirmed, and the tumor grade of gliomas was classified according to the method of Kleihues and Cavenee (28).

Controls were selected from patients admitted to the same hospitals for a variety of conditions including injuries and nonmalignant diseases of the musculoskeletal, circulatory, digestive, and nervous systems. Controls were frequency matched to cases (1:1 ratio) by age (within 10 years), sex, race or ethnic group, and proximity of residence to the same hospital. Eighty-six percent (n = 799) of eligible controls consented to participate.

Data collection

Cases and controls or their proxies were interviewed in the hospital by research nurses using computer-assisted questionnaires. Questions were asked to elicit demographic data, medical history, occupational history, cellular telephone use, and other suspected risk factors for brain tumors. At the end of the interview, each subject or proxy was given a self-administered questionnaire to be completed in the hospital or at home. Subjects who were mentally impaired or otherwise ill were usually assisted in completion of the self-administered questionnaire by a spouse or the nurse coordinator. The self-administered questionnaire asked questions about the use of 10 common electrical appliances used near the head (hair dryer, curling iron, electric shaver (face only), electric heating pad and vibrating massage device (used near the head, neck, or shoulders), electric blanket, water bed with heater, sound system with a headset, computer, television) that have the potential for high magnetic field exposure to the brain and central nervous system when used close to the body. Microwave ovens have the potential for high magnetic flux density, but they are not typically used close to the body. Although cellular telephones are used next to the head, the principal exposure is radiofrequency radiation, which was evaluated previously in this data set (27). Electric clocks were not considered, because they are not a significant source of EMF (19). We included three other appliances that are not used close to the body (humidifier, stereo system without a headset, and electric stove) in order to evaluate the likely importance of recall bias among study subjects.

Follow-up telephone calls were placed to subjects to remind them to return the completed questionnaire. The response rate for the self-administered questionnaire was 86.7 percent for 678 cases (410 with glioma, 178 with meningioma, and 90 with acoustic neuroma) and 85.9 percent for 686 controls. Adjusting the response rate to reflect completion of both the initial in-person interview and self-administered questionnaire yielded response rates of 79.8 percent for cases and 73.9 percent for controls. Nonrespondent cases tended to be older, male, and non-White; to have a lower income level; to have completed fewer years of education; and to be more likely to have been diagnosed with a glioma compared with respondent cases. The nonrespondent controls tended to be younger and non-White and to have completed fewer years of education than the respondent controls.

Similarly worded questions for 12 of 14 appliances focused on ever use (at least three times throughout life), age at first and last use, and frequency of use (times per day, week, or month), and for nine appliances, we asked about intensity of use (average number of minutes or hours the appliance was typically used per use). The number of months an appliance was used within a year was collected for hair

TABLE 1. Characteristics of brain tumor case and control respondents by self-administered questionnaire, United States, 1994–1998

	Glioma* (*n* = 410)		Meningioma (*n* = 178)		Acoustic neuroma (*n* = 90)		Controls (*n* = 686)	
	No.	%	No.	%	No.	%	No.	%
Location of hospital								
Phoenix, AZ	194	47.3	89	50.0	69	76.7	336	49.0
Boston, MA	130	31.7	72	40.4	20	22.2	191	27.8
Pittsburgh, PA	86	21.0	17	9.6	1	1.1	159	23.2
Age (years) at computer-aided personal interview								
18–39	113	27.5	29	16.3	17	18.9	204	29.7
40–59	152	37.1	81	45.5	47	52.2	270	39.4
≥60	145	35.4	68	38.2	26	28.9	212	30.9
Sex								
Male	225	55.0	41	23.0	35	39.0	312	45.5
Female	185	45.0	137	77.0	55	61.0	374	54.5
Income ($)								
<15,000	34	8.2	15	8.4	2	2.2	103	15.0
15,000–24,000	63	15.4	27	15.2	8	8.9	102	14.9
25,000–34,000	58	14.1	26	14.6	12	13.3	86	12.5
35,000–49,000	72	17.6	29	16.3	25	27.8	117	17.1
50,000–74,000	72	17.6	32	18.0	16	17.8	133	19.4
≥75,000	91	22.2	35	19.7	23	25.6	103	15.0
Don't know/missing	20	4.9	14	7.8	4	4.4	42	6.1
Education								
<High school	46	11.2	21	11.8	4	4.4	83	12.1
High school graduate	102	24.9	52	29.2	26	28.9	196	28.6
1–3 years of college	115	28.1	62	34.8	19	21.1	217	31.6
≥4 years of college	135	32.9	42	23.6	40	44.5	171	24.9
Don't know/missing	12	2.9	1	0.6	1	1.1	19	2.8

Table continues

dryers, electric blankets, and bedroom humidifiers only. For electric blanket use, temperature setting and year of purchase were queried, because blankets manufactured before 1990 emit higher magnetic fields than do more recent models. We also inquired whether the electric shaver was rechargeable or plug-in, because plug-in shavers produce ELF-EMF exposures, whereas rechargeable shavers do not. For two appliances, television and electric stove, we inquired about the number of hours of use per day or week in the past 10 years, as well as distance from the television in feet. In March 1995, after a few months of data collection, we added questions about home (nonoccupational) computer use in the past 10 years and collected information from 77 percent of eligible cases and 80 percent of controls who had completed the self-administered questionnaire.

Data analysis

Unconditional logistic regression was used to investigate the association between type of brain tumor and individual appliance use. Odds ratios and 95 percent Wald-type confidence intervals were computed. We chose not to combine appliances into one composite exposure measure, because it was not clear to us what would be the appropriate metric for exposure. Further, subjects' patterns of use and combination of appliances varied so considerably that a single metric summarizing exposure would likely yield a meaningless index of exposure. However, when we observed nonnull findings for ever use of an appliance, we calculated a cumulative use variable for that appliance on the basis of the available exposure variables (e.g., number of years used, number of months per year, times used per month or week, and number of minutes used per time). In the final model, regression coefficients were adjusted for age and date at the initial hospital interview, sex, race, income, education, location of hospital, distance in miles from home to the hospital, and whether the subject required assistance when responding to the self-administered questionnaire. Cases and controls differed by income and educational levels (29), and we were concerned that appliance use may be related to income level. When education and income were included in the model, the odds ratios changed considerably for some of the appliances

TABLE 1. Continued

	Glioma* (*n* = 410)		Meningioma (*n* = 178)		Acoustic neuroma (*n* = 90)		Controls (*n* = 686)	
	No.	%	No.	%	No.	%	No.	%
Race								
White/non-Hispanic	371	90.5	142	79.8	80	88.9	596	86.9
White/Hispanic	3	0.7	1	0.5	1	1.1	11	1.6
Black	4	1.0	9	5.1	0	0.0	16	2.3
Other	32	7.8	26	14.6	9	10.0	63	9.2
Distance from hospital (miles†)								
<5	103	25.1	56	31.5	22	24.4	220	32.1
5–9	124	30.3	53	29.8	29	32.3	195	28.4
10–14	103	25.1	34	19.1	15	16.7	141	20.6
15–49	37	9.0	15	8.4	2	2.2	56	8.1
≥50	43	10.5	20	11.2	22	24.4	74	10.8
Respondent to computer-aided personal interview								
Self only	262	63.9	140	78.7	81	90.0	644	93.9
Proxy	62	15.1	13	7.3	2	2.2	27	3.9
Subject + proxy	86	21.0	25	14.0	7	7.8	15	2.2
Help completing self-administered questionnaire								
No	183	44.6	114	64.0	62	68.9	505	73.6
Yes	227	55.4	64	36.0	28	31.1	181	26.4

* High-grade gliomas included glioblastoma (*International Classification of Diseases for Oncology* (ICD-O) codes 9440 and 9441 (*n* = 195)); gliosarcoma (ICD-O code 9442 (*n* = 4)); anaplastic astrocytoma (ICD-O code 9401 (*n* = 58)); anaplastic ependymoma (ICD-O code 9392 (*n* = 1)); anaplastic oligodenroglioma (ICD-O code 9451 (*n* = 7)); anaplastic mixed oligoastrocytoma (ICD-O code 9380 (*n* = 5) and ICD-O code 9382 (*n* = 12)); and other anaplastic glioma (ICD-O code 9505 (*n* = 1)). Low-grade gliomas included oligodendroglioma (ICD-O code 9450 (*n* = 45)); diffuse astrocytoma (ICD-O codes 9400, 9411, 9420, and 9421 (*n* = 27)); mixed oligoastrocytoma (ICD-O codes 9380 and 9382 (*n* = 21)); ganglioglioma (ICD-O code 9505 (*n* = 15)); ependymoma (ICD-O codes 9383 and 9391 (*n* = 8)); and neurocytoma (ICD-O code 9506 (*n* = 3)). These classifications are based on those of Kleihues and Cavenee (28). Additionally, there were eight gliomas that were not included in the high-grade or low-grade classifications: astroblastoma (ICD-O code 9430 (*n* = 1)); medulloblastoma (ICD-O code 9470 (*n* = 4)); primitive neuroectodermal tumor (ICD-O code 9473 (*n* = 1)); and neuroblastoma (ICD-O code 9500 (*n* = 2)).

† One mile = 1.61 km.

when there were few exposed cases, so both of these variables were retained in the model. We also stratified analyses for specific appliances by hospital, age at interview, sex, education, income, and subject or proxy response to the self-administered questionnaire to examine the possible modifying effects of these variables on the odds ratios. Because control subjects were characterized by differing income and education according to diagnostic categories, we thought that appliance use might vary by reason for hospitalization. Therefore, we further analyzed the data by systematically excluding different subgroups of controls (i.e., those hospitalized for trauma, diseases of the musculoskeletal system, diseases of the circulatory system, and other discharge diagnoses). When we did so, the odds ratios remained essentially unchanged.

We estimated odds ratios associated with appliance use for low-grade and high-grade glioma separately, because there is evidence that the etiology may differ by tumor grade (3). For specific appliances, such as curling irons and electric shavers, analyses were restricted to females and males, respectively. Hair dryer use was analyzed separately for males and females since patterns of use differed by sex. Duration of use of an individual appliance was calculated from the age or year first used and age or year last used. We evaluated the use of appliances by level of use on the basis of the distribution of exposure patterns among the controls.

RESULTS

Very few differences were noted between cases and controls, except that more cases, especially those diagnosed with a glioma, required additional help or a proxy to respond to the initial, in-hospital interview and the self-administered questionnaire (table 1). Over half of the glioma cases and one third of the other cases reported receiving help to answer the self-administered questionnaire compared with only 26 percent of the control subjects. Additionally, the sex ratio of cases differed among the tumor categories (male:female ratio = 1.2 for glioma, 0.3 for meningioma, and 0.6 for acoustic neuroma). Cases with an acoustic neuroma tended to report higher incomes and level of education compared with the other cases or controls (29).

TABLE 2. Risk of adult brain tumors associated with any use (at least three times throughout life) of selected electrical appliances, United States, 1994–1998

Appliance* and any use	Glioma			Meningioma			Acoustic neuroma			No. of controls†
	No. of cases†	OR‡,§	95% CI‡	No. of cases†	OR§	95% CI	No. of cases†	OR§	95% CI	
Hair dryer										
Males and females										
Never	91	1.0		29	1.0		15	1.0		165
Ever	279	1.7	1.1, 2.5	132	1.3	0.7, 2.3	69	1.5	0.7, 3.3	490
Males										
Never	84	1.0		22	1.0		14	1.0		146
Ever	111	1.7	1.1, 2.7	16	1.6	0.7, 3.9	19	1.4	0.6, 3.6	131
Females										
Never	7	1.0		7	1.0		1	1.0		19
Ever	168	2.2	0.7, 6.5	116	1.2	0.4, 3.3	50	1.2	0.1, 11	317
Electric shaver (males)										
Never	57	1.0		2	1.0		11	1.0		102
Ever	142	1.0	0.6, 1.5	35	10.9	2.3, 50	22	0.6	0.2, 1.6	206
Microwave oven										
Never	9	1.0		4	1.0		1	1.0		29
Ever	361	2.0	0.9, 4.8	155	1.5	0.5, 4.7	83	1.9	0.2, 16	583
Curling iron (females)										
Never	49	1.0		42	1.0		10	1.0		93
Ever	125	1.1	0.7, 1.8	80	0.8	0.5, 1.3	41	1.3	0.6, 3.1	242
Vibrating massage device										
Never	292	1.0		128	1.0		65	1.0		493
Ever	78	1.1	0.7, 1.5	33	1.0	0.6, 1.6	19	1.1	0.6, 1.9	119
Electric blanket										
Never	159	1.0		73	1.0		36	1.0		282
Ever	216	1.0	0.7, 1.3	88	0.9	0.6, 1.3	48	0.8	0.5, 1.3	336

Table continues

Ever use of a hair dryer was significantly associated with glioma (odds ratio (OR) = 1.7, 95 percent confidence interval (CI): 1.1, 2.5) (table 2), with little apparent difference between high-grade glioma (OR = 1.9, 95 percent CI: 1.2, 2.9) and low-grade glioma (OR = 1.5, 95 percent CI: 0.7, 3.0). The association with hair dryer use was significant for males (OR = 1.7, 95 percent CI: 1.1, 2.7) but not for females (OR = 2.2, 95 percent CI: 0.7, 6.5). Ever use of an electric shaver was significantly associated with meningioma in males (OR = 10.9, 95 percent CI: 2.3, 50); however, this estimate was based on only two nonexposed and 35 exposed cases. The odds ratios for meningioma were markedly increased for both rechargeable (OR = 10.6, 95 percent CI: 1.7, 68) and plug-in (OR = 16.5, 95 percent CI: 2.8, 95) shavers. The odds ratios associated with ever use of a microwave oven were nonsignificantly increased for all three types of brain tumor: glioma (OR = 2.0, 95 percent CI: 0.9, 4.8), meningioma (OR = 1.5, 95 percent CI: 0.5, 4.7), and acoustic neuroma (OR = 1.9, 95 percent CI: 0.2, 16).

When we restricted the analyses to subject-only replies, the results for ever use of a hair dryer, electric shaver, and microwave changed only slightly. No clear pattern of increasing odds ratios with increasing years of use of hair dryers emerged for glioma for either males or females separately or combined (table 3). For meningioma, the odds ratios increased with increasing years of use of electric shavers. The odds ratios associated with microwave oven use decreased slightly as duration of use increased for glioma and meningioma. Odds ratios less than unity were noted for long-term users of curling irons, electric heating pads, electric blankets, and sound systems with headsets. For electric shavers, odds ratios were increased with increased frequency of use for meningioma only, but they showed no dose-response effect (for 1–3 times per month: OR = 18; for 1–6 times per week: OR = 12; and for daily use: OR = 15) (table 4). Odds ratios decreased with increasing frequency of use for hair dryers and microwave ovens.

Odds ratios for meningioma decreased with increasing time since last use of an electric shaver (for current users, last used within 1–2 years, and last used ≥3 years ago: ORs

TABLE 2. Continued

Appliance* and any use	Glioma			Meningioma			Acoustic neuroma			No. of controls†
	No. of cases†	OR§	95% CI	No. of cases†	OR§	95% CI	No. of cases†	OR§	95% CI	
Electric heating pad										
Never	203	1.0		85	1.0		33	1.0		287
Ever	169	0.7	0.5, 0.9	75	0.7	0.5, 1.0	51	1.0	0.6, 1.7	330
Water bed with heater										
Never	278	1.0		125	1.0		65	1.0		429
Ever	94	0.8	0.6, 1.2	36	0.8	0.5, 1.3	19	0.4	0.2, 0.8	186
Electric stove										
Never	81	1.0		34	1.0		13	1.0		150
Ever	288	1.1	0.8, 1.6	122	1.2	0.4, 3.2	70	1.0	0.5, 2.0	457
Computer, nonoccupational										
Never	161	1.0		89	1.0		26	1.0		313
Ever	143	1.2	0.8, 1.7	55	0.8	0.5, 1.2	47	1.7	0.9, 3.2	234
Television										
Never	2	1.0		0	1.0		0	1.0		4
Ever	373	1.7	0.3, 11	159	∞	<0.001, ∞	83	∞	<0.001, ∞	610
Sound system										
With headset										
Never	181	1.0		90	1.0		47	1.0		323
Ever	190	1.1	0.8, 1.5	72	0.9	0.6, 1.4	37	0.6	0.4, 1.1	294
Without headset										
Never	42	1.0		19	1.0		7	1.0		73
Ever	325	0.7	0.4, 1.2	138	1.1	0.6, 2.1	74	0.9	0.4, 2.4	525
Bedroom humidifier										
Never	294	1.0		127	1.0		68	1.0		483
Ever	74	0.9	0.7, 1.3	33	0.9	0.6, 1.5	16	0.8	0.4, 1.5	129

* Appliances ranked in the order of potential magnetic field exposure on the bases of strength of the magnetic field and distance from the body during typical use (35).
† Totals may differ because of missing data.
‡ OR, odds ratio; CI, confidence interval.
§ Unconditional logistic regression adjusted for age, gender, income, education, race, center, distance from center, date of interview, and help filling out the self-administered questionnaire.

= 13.7, 12.1, and 5.5, respectively). However, odds ratios for glioma did not vary by time since last use of a hair dryer (ORs = 1.7, 1.5, and 1.7) or a microwave oven (ORs = 2.1, 1.9, and 2.6).

On average, females spent twice as long drying their hair as males did (18 minutes vs. 9 minutes). However, the odds ratios increased for 1–5, 6–14, and 15 or more minutes of use of hair dryers for men (ORs =1.3, 2.4, and 2.6) but not for women (ORs = 1.9, 1.5, and 1.2).

Not surprisingly, the odds ratio patterns for cumulative measures of use for electric shavers, hair dryers, and microwave ovens are similar to the odds ratio patterns for duration presented in table 3. Odds ratios for meningioma increased with increasing tertiles of cumulative minutes of use for electric shavers (ORs = 6.8, 10.9, 17.9). For microwave ovens and hairdryers, there was no consistent increase in the odds ratios with increasing cumulative use.

The odds ratios for glioma for daily use of electric blankets did not differ by year of purchase (before 1990: OR = 0.77, 95 percent CI: 0.5, 1.2; 1990 or later: OR = 0.87, 95 percent CI: 0.3, 2.2) or by temperature setting (low: OR = 1.14, 95 percent CI: 0.6, 2.2; medium: OR = 0.68, 95 percent CI: 0.4, 1.1; high: OR = 0.65, 95 percent CI: 0.2, 1.9). Additionally, odds ratios remained below unity for increasing months of use per year of electric blankets.

DISCUSSION

We evaluated the association of 14 commonly used household appliances with three distinct types of intracranial tumors of the brain and nervous system and found little evidence of association for 12 of the 14 appliances. Given the large number of comparisons that were made, several odds ratios would have been expected to have been increased by chance alone. We noted statistically significantly elevated odds ratios for hair dryers and glioma and for electric shavers and meningioma. There was a dose-response effect for cumulative use of an electric shaver, but not for hair dryers. Both of these appliances are used very close to the head and have the potential for increasing personal exposure to ELF-EMF. At the same time, however, use in proximity to the head may increase the likelihood of recall bias for these

TABLE 3. Risk of brain tumors associated with duration of appliance use, United States, 1994–1998

Appliance* and duration	Glioma			Meningioma			Acoustic neuroma			No. of controls†
	No. of cases†	OR‡,§	95% CI‡	No. of cases†	OR§	95% CI	No. of cases†	OR§	95% CI	
Hair dryer										
Males and females										
Never	91	1.0		29	1.0		15	1.0		165
1–9 years	41	2.2	1.2, 3.9	7	0.8	0.3, 2.1	5	1.4	0.4, 4.5	51
10–17 years	56	1.7	1.0, 2.9	15	0.9	0.4, 2.1	11	1.5	0.6, 4.2	80
18–29 years	76	1.3	0.8, 2.2	37	1.2	0.5, 2.3	24	1.6	0.6, 4.2	138
≥30 years	83	1.5	0.9, 2.5	52	1.4	0.6, 2.7	27	1.5	0.6, 3.9	135
Males										
Never	84	1.0		22	1.0		14	1.0		146
1–9 years	27	2.0	1.0, 4.0	4	1.8	0.5, 7.3	2	0.7	0.1, 4.0	30
10–17 years	26	1.4	0.7, 2.8	2	0.8	0.2, 4.3	6	2.9	0.8, 10	36
18–29 years	30	1.3	0.7, 2.5	6	1.5	0.5, 4.8	8	1.1	0.3, 3.9	39
≥30 years	16	2.2	0.9, 5.1	2	1.3	0.2, 8.0	2	1.2	0.2, 7.9	15
Females										
Never	7	1.0		7	1.0		1	1.0		19
1–9 years	14	3.7	1.0, 14	3	0.4	0.1, 2.2	3	2.2	0.2, 27	21
10–17 years	30	3.0	0.9, 10	13	0.7	0.2, 2.7	5	0.7	0.1, 8.0	44
18–29 years	46	1.7	0.5, 5.6	31	0.9	0.3, 2.7	16	1.3	0.1, 13	99
≥30 years	67	2.0	0.6, 6.1	50	1.1	0.4, 3.3	25	1.4	0.2, 13	120
Electric shaver (males)										
Never	57	1.0		2	1.0		11	1.0		93
1–8 years	35	1.0	0.5, 1.8	4	3.9	0.6, 26	5	0.6	0.2, 2.2	50
9–28 years	49	1.1	0.6, 2.0	12	15.6	2.8, 85	4	0.4	0.1, 1.6	55
≥29 years	45	0.7	0.4, 1.3	15	16.3	3.0, 89	12	0.8	0.3, 2.4	64
Microwave oven										
Never	9	1.0		4	1.0		1	1.0		29
1–11 years	130	2.4	1.0, 5.7	57	1.6	0.5, 5.2	22	1.9	0.2, 17	189
12–17 years	125	2.0	0.8, 4.9	48	1.5	0.4, 5.0	35	2.6	0.3, 23	193
≥18 years	93	1.7	0.7, 4.2	41	1.1	0.3, 3.9	24	1.4	0.1, 12	171
Curling iron (females)										
Never	49	1.0		42	1.0		10	1.0		93
≤12 years	44	1.2	0.6, 2.1	22	0.7	0.4, 1.4	11	1.2	0.4, 3.4	75
13–22 years	38	1.4	0.7, 2.7	26	1.1	0.6, 2.2	18	2.3	0.9, 6.3	67
≥23 years	27	0.7	0.3, 1.2	22	0.6	0.3, 1.2	10	0.9	0.3, 2.6	75
Vibrating massage device										
Never	292	1.0		128	1.0		65	1.0		493
≤2 years	12	0.6	0.3, 1.2	9	1.3	0.5, 3.1	4	0.7	0.2, 2.4	26
3–10 years	22	1.2	0.7, 2.3	5	0.6	0.2, 1.6	5	1.0	0.3, 2.9	34
≥11 years	10	1.1	0.4, 2.7	4	1.3	0.4, 4.4	3	1.4	0.3, 5.7	13

Table continues

appliances in brain tumor patients. The relative contribution of appliances to a subject's total magnetic field exposure in homes can be difficult to estimate because of the unknown distance of the subject in relation to the appliance and how often the appliance is turned on or off (30). Even if the exposure level to the brain, meninges, and acoustic nerves was high, most household appliances are usually used for a short period of time.

The strongest finding of an association was for electric shavers and meningioma in men. Magnetic field measurements have demonstrated considerable variability in field strength among different electric shavers, and the measurements also show that the average magnetic field intensity for electric shavers is among the highest observed for household appliances (18, 31, 32). Based on the assumption that the distance from the magnetic field source inside the shaving

TABLE 3. Continued

Appliance* and duration	Glioma			Meningioma			Acoustic neuroma			No. of controls†
	No. of cases†	OR§	95% CI	No. of cases†	OR§	95% CI	No. of cases†	OR§	95% CI	
Electric blanket										
Never	159	1.0		73	1.0		36	1.0		282
≤5 years	72	1.0	0.7, 1.5	29	1.0	0.6, 1.8	15	0.9	0.4, 1.9	110
6–10 years	43	0.8	0.5, 1.3	15	0.7	0.3, 1.3	6	0.4	0.1, 1.0	76
≥11 years	44	0.7	0.4, 1.2	21	0.7	0.4, 1.3	20	1.0	0.5, 2.1	82
Electric heating pad										
Never	203	1.0		85	1.0		33	1.0		287
1–10 years	55	1.0	0.7, 1.6	17	0.6	0.3, 1.2	13	1.4	0.6, 3.0	85
11–25 years	46	0.7	0.4, 1.0	21	0.7	0.4, 1.2	13	1.1	0.5, 2.4	97
≥26 years	44	0.4	0.3, 0.8	30	0.7	0.4, 1.2	18	0.9	0.4, 1.8	105
Water bed with heater										
Never	278	1.0		125	1.0		65	1.0		429
≤4 years	26	0.7	0.4, 1.1	11	0.7	0.3, 1.5	4	0.3	0.1, 1.0	63
5–10 years	22	0.6	0.3, 1.0	8	0.7	0.3, 1.5	6	0.4	0.2, 1.2	55
≥11 years	30	1.2	0.7, 2.0	11	1.0	0.5, 2.2	7	0.6	0.2, 1.6	45
Computer, nonoccupational										
Never	161	1.0		89	1.0		26	1.0		313
≤4 years	36	1.4	0.8, 2.3	18	1.3	0.7, 2.6	11	1.8	0.7, 4.3	56
5–10 years	46	1.5	0.9, 2.5	4	0.6	0.3, 1.3	12	1.3	0.5, 3.1	64
≥11 years	20	0.9	0.5, 1.7	11	0.6	0.3, 1.4	12	1.6	0.7, 4.0	44
Sound system										
With headset										
Never	181	1.0		90	1.0		47	1.0		323
≤6 years	55	0.9	0.6, 1.4	21	0.9	0.5, 1.6	13	0.8	0.4, 1.7	90
7–17 years	59	1.5	1.0, 2.4	23	1.3	0.7, 2.4	10	0.7	0.3, 1.7	72
≥18 years	30	0.6	0.4, 1.1	11	0.6	0.6, 1.2	10	0.6	0.3, 1.3	81
Without headset										
Never	42	1.0		19	1.0		7	1.0		73
≤25 years	101	1.0	0.6, 1.8	33	1.2	0.5, 2.5	12	0.7	0.2, 2.1	152
26–40 years	97	0.7	0.4, 1.2	38	0.9	0.4, 1.9	31	1.0	0.4, 2.9	172
≥41 years	90	0.6	0.3, 1.0	54	1.1	0.6, 1.2	29	1.1	0.4, 3.0	158
Bedroom humidifier										
Never	294	1.0		127	1.0		68	1.0		483
≤4 years	17	0.7	0.4, 1.4	7	0.8	0.3, 2.0	8	1.6	0.6, 3.9	36
5–10 years	2	1.1	0.6, 2.0	5	0.5	0.2, 1.5	2	0.3	0.1, 1.6	35
≥11 years	11	0.9	0.6, 2.0	8	1.6	0.6, 4.3	2	0.7	0.1, 3.4	16

* Appliances ranked in the order of potential magnetic field exposure on the bases of strength of the magnetic field and distance from the body during typical use (35).
† Totals may differ because of missing data.
‡ OR, odds ratio; CI, confidence interval.
§ Unconditional logistic regression adjusted for age, gender, education, family income, race, center, distance from center, date of interview, and help filling out the self-administered questionnaire.

unit to the brain probably ranges from 8 to 10 cm when shaving near the ear and from 15 to 20 cm when shaving the chin, measurements indicate that the brain could be exposed to maximum magnetic fields of between 50 and 350 μT (18). Based on these assumptions, exposure to the brain and meninges from magnetic fields from shavers could be large, but since shavers are used typically for short periods of time, they would not contribute much to an individual's time-weighted average exposure.

There are additional reasons for questioning whether the association between meningioma and use of an electric shaver is likely to be causal. First, the findings are based on just two nonexposed cases and are highly unstable. Second, men had much longer cumulative durations of use for hair

TABLE 4. Risk of adult brain tumors associated with frequency of use of selected electrical appliances, United States, 1994–1998

Appliance and measure	Glioma			Meningioma			Acoustic neuroma			No. of controls*
	No. of cases*	OR†,‡	95% CI†	No. of cases*	OR‡	95% CI	No. of cases*	OR‡	95% CI	
Hair dryer										
Males and females										
Never	91	1.0		29	1.0		15	1.0		165
<1/month	27	1.9	1.0, 3.6	13	1.4	0.6, 3.4	4	0.9	0.3, 3.5	38
1–3/month	52	1.9	1.1, 3.2	31	1.5	0.7, 3.2	14	2.2	0.9, 5.8	77
1–6/week	108	1.8	1.1, 2.8	47	1.1	0.5, 2.1	25	1.3	0.5, 3.2	171
Daily	89	1.4	0.9, 2.3	36	1.0	0.5, 2.1	26	1.6	0.6, 3.8	158
Males										
Never	84	1.0		22	1.0		14	1.0		146
<1/month	14	2.0	0.8, 5.1	3	5.2	1.0, 26	3	2.2	0.4, 13	13
1–3/month	18	2.0	0.9, 4.5	2	1.3	0.2, 7.5	2	0.9	0.1, 5.2	20
1–6/week	33	1.6	0.9, 3.0	5	1.8	0.5, 6.1	6	1.7	0.5, 6.0	42
Daily	45	1.5	0.8, 2.7	6	1.3	0.4, 3.9	8	1.4	0.4, 4.6	54
Females										
Never	7	1.0		7	1.0		1	1.0		19
<1/month	13	2.2	0.6, 8.2	10	1.3	0.4, 4.3	1	0.2	0.01, 4.1	25
1–3/month	34	2.4	0.8, 7.7	29	1.5	0.5, 4.6	12	2.2	0.2, 21	57
1–6/week	75	2.1	0.7, 6.5	42	0.8	0.3, 2.4	19	1.0	0.1, 9.1	129
Daily	44	1.6	0.5, 8.2	30	0.8	0.4, 4.3	18	1.1	0.1, 10.8	104
Electric shaver (males)										
Never	57	1.0		2	1.0		11	1.0		93
<1/month	7	0.5	0.2, 1.4	1	2.1	0.1, 32	0	0.0		18
1–3/month	15	1.3	0.5, 2.9	4	18	2.2, 144	4	1.4	0.3, 6.4	20
1–6/week	44	1.0	0.6, 1.8	9	12	2.3, 67	6	0.8	0.2, 2.8	53
Daily	64	0.8	0.5, 1.5	19	15	2.9, 80	8	0.5	0.2, 1.6	79
Microwave oven (males and females)										
Never	9	1.0		4	1.0		1	1.0		29
<1/month	9	2.4	0.7, 9.0	2	0.8	0.1, 5.4	1	1.0	0.1, 21	12
1–3/month	32	3.0	1.1, 8.1	11	1.8	0.5, 6.9	5	2.0	0.2, 21	39
1–6/week	154	2.1	0.9, 5.1	57	1.4	0.4, 4.6	36	2.0	0.2, 17	233
Daily	163	1.9	0.8, 4.5	85	1.6	0.5, 5.2	39	1.7	0.2, 15	294

* Totals may differ because of missing data on exposure variables.

† OR, odds ratio; CI, confidence interval.

‡ Unconditional logistic regression adjusted for age, gender, education, family income, race, center, distance from center, date of interview, and help filling out the self-administered questionnaire.

dryers than for electric shavers, but meningioma was not significantly associated with use of hair dryers. Third, one must question the plausibility of a ten- or 11-fold increased risk associated with such a common exposure as use of an electric shaver. The exposure is unique to males, yet meningioma is two to three times more common in women than men. This lack of internal consistency and plausibility raises doubts that the association is causal and points to an alternative possible explanation, such as recall bias.

Rechargeable shavers operate off batteries powered by direct current sources and do not produce ELF-EMF exposures, but, like plug-in shavers, they do generate higher frequency transients (31), brief magnetic field events that occur on a time scale of the order of 16 milliseconds, that is, the duration of one 60-Hz cycle (33). Similarity in odds ratios for the two types of shaver would suggest that, if EMF exposure is associated with meningioma risk, then it is not ELF-EMF exposures that are important but, rather, some other aspect of exposure, such as high-frequency transients (31). However, it is possible that our questionnaire failed to capture relevant aspects of the type or manner of shaver use, resulting in misclassification of use. Both types of shaver might have been used by the same subject, but we collected information only on the type of electric shaver used more than half of the time. We cannot distinguish between those subjects who used only one type of shaver and those subjects

who may have used more than one type. Some rechargeable shavers can be used either plugged in or cordless, and we did not collect this type of information. Either possibility could result in misclassification with respect to type of electric shaver use.

High-frequency transients are produced by both electric shavers and hair dryers, and, in measurements of a small sample of five hair dryers and seven shavers, hair dryers tended to have higher magnitude transients than did shavers (31). If high-frequency transients are causally associated with brain tumors in adults, then we would have expected to have seen stronger and more consistent associations with hair dryers than we did. In our study, women reported using hair dryers for longer periods of time than did men, but significantly elevated risks for glioma were evident only for men. Although hand-held hair dryers produce intense magnetic fields near the source, the measurement studies suggest that hair dryers increase the background time-weighted average ELF fields by only 3 percent, because hair dryers, even when used daily, are used typically for very short intervals of time (19). Measurements of the magnetic flux density show that hand-held hair dryers have less variability in field strength than do electric shavers, and that hair dryers have an average magnetic field intensity between one and two orders of magnitude lower than the average for electric shavers (18, 31, 32). Our conflicting results for males and females raise doubts about a causal association between use of hair dryers and brain tumors.

With respect to other appliances, the nonsignificant increases in odds ratios from 1.5- to twofold for the three categories of brain tumors and use of microwave ovens are not convincing, as there were no consistent dose-response patterns. Properly functioning microwave ovens should not emit microwave radiation outside the oven. The primary exposure is from the ELF-EMF produced by the motor, but microwave ovens typically are not used close to the body. Although a nonsignificant, positive association was noted previously between use of an electric blanket and glioma (20), we did not find an association between electric blankets and brain tumors nor for personal massage devices used near the head, neck, and shoulders. Electric blankets manufactured prior to 1990 can result in significant exposure to magnetic fields (34), yet we found no evidence of risk related to blanket use during that time period in our study. We also did not confirm an association between use of an electric water bed heater and meningioma (20).

If magnetic fields from electrical appliances accelerated the growth of preclinical tumors, as has been suggested (11), then odds ratios would be expected to decrease with time since last use of an appliance. We observed this pattern for electric shavers only.

Strengths of our study include the rapid ascertainment of brain tumor cases for interview after diagnosis, the high response rates for cases and controls, and a much larger number of cases and controls than was included in the only other study of adult brain tumors and appliances (20).

Several limitations of the study, however, should be noted. One is the potential for recall bias that can lead to the differential misclassification of exposure due to overreporting of appliance use by cases and underreporting by controls. Almost half of the cases and a quarter of the controls received help in answering the questionnaire, so we adjusted analyses for assistance in completing the self-administered questionnaire. Odds ratios tended to be higher when analyses were restricted to cases and controls who responded without assistance. About 10 percent of responses to questions about ever use of appliances were unknown, incomplete, or missing, and cases consistently had more missing values than did controls. However, when we estimated associations for missing values, the odds ratios were usually less than unity. For some appliances, the highest odds ratios were observed for those who reported using an appliance least frequently, which may suggest a possible reporting bias.

Except for television, we did not collect data on the distance between the subject and appliances. Misclassification by type of electric shaver may have occurred, because we asked only about the type of electric shaver used more than half of the time, and more than one type may have been used in the past. In addition, we did not capture information on intermittent use of appliances. It was assumed that an appliance was used for the entire duration that was reported. There are other appliances used near the head that we did not include in this study, and we did not attempt to assess cumulative exposure across different appliances.

Finally, hospital controls may have influenced the risk estimates, because they tend to be of lower socioeconomic status than cases and may possibly use appliances differently. However, the hospital controls in this study were diverse with respect to socioeconomic status (29), and all of the risk estimates were adjusted for both education and income, which would have minimized the residual effect of socioeconomic status on these estimates.

To our knowledge, this is the first epidemiologic study of adult brain tumors to evaluate associations with hair dryers and electric shavers, and these data must be viewed as exploratory. The inconsistent associations that we noted with hair dryers make these findings difficult to interpret. The high odds ratio for meningioma seen among long-term users of electric shavers is noteworthy but should be interpreted cautiously pending replication in other study populations with greater numbers of meningioma cases. At present, the finding lacks biologic and epidemiologic plausibility. The overall lack of internal consistency and potential recall bias in the observed associations argue against a causal role of ELF-EMF from electrical appliances used close to the body in the etiology of adult brain tumors.

ACKNOWLEDGMENTS

The authors gratefully acknowledge Bill Kaune for his insightful comments and advice; the Brain Tumor/EMF Advisory Panel for constructive comments; Christel McCarty and Henry Chen of IMS, Silver Spring, Maryland, for programming support; Tim Wilcosky, Research Triangle Institute, Research Triangle Park, North Carolina, for overall study direction; and the research nurses who interviewed the study subjects.

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